Quarterly Report
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Abstract

Our major achievements of this quarter were: (1) the delivery of our MODIS Beta-3 cloud retrieval algorithm software for integration and testing, (2) the creation of a Cloud Absorption Radiometer (CAR) operation manual and standardized data HDF format for the science community, (3) the execution of a successful SCAR-B field campaign in Brazil with the MODIS Airborne Simulator (MAS) and CAR participation, (4) initial submission and subsequent revisions of a MAS instrumentation paper submitted to the *Journal of Atmospheric and Oceanic Technology*, and (5) completion of a new paper submitted for publication to the *Journal of the Atmospheric Sciences* on the sensitivity of inhomogeneous ice cloud at three MODIS wavelengths.

I. Task Objectives

With the use of related airborne instrumentation, such as the MODIS Airborne Simulator (MAS) and Cloud Absorption Radiometer (CAR) in intensive field experiments, our primary objective is to extend and expand algorithms for retrieving the optical thickness and effective radius of clouds from radiation measurements to be obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS). The secondary objective is to obtain an enhanced knowledge of surface angular and spectral properties that can be inferred from airborne directional radiance measurements.

II. Task Progress

a. MODIS-related Instrumental Research

The MAS 50-channel Level-1B processing software has been completed by Paul Hubanks. Additional metadata parameters, including analog gain and offset, MAS clock time (which had to be aligned with the GPS navigation data), Head1/2 counts and temperatures, are now stored in the HDF output. The blackbody count changes (due to DC drift) in the visible and near-infrared channels have been compensated and those of the infrared channels in port 3 and 4 (due to a Òsaw-tooth effectÓ in the new digitizer) are currently under developing by the Ames Data Facility. Some of the Level-0 data from the Snow/Ice Mapping Mission (April, Alaska) and ARMCAS (June, Alaska) campaigns were processed through the Level-1B software system to create browse imagery. These test browse images of MAS 50-channel data have been included in the Browse Imagery Archive in the MAS World Wide Web site.

The final calibration data for ARMCAS and SCAR-B are currently in preparation by Tom Arnold. The absolute calibrations measured by John Cooper for each spherical integrating source were used to calculate source radiance over MAS bandpass for processing all lamp levels at one time. These radiance values for each lamp level and each MAS band were combined with MAS count values from which radiance per count are computed. Such a procedure was followed for the two ARMCAS calibrations. These data will be compared to the 30-inch Ames calibrations. During SCAR-B, three separate MAS calibrations were conducted with the MAS elevated above a 20-inch integrating hemisphere shipped to Brasilia. Tom Arnold and Mike Fitzgerald (Ames Research Center) have worked on comparison of these data to those of ARMCAS preflight data, as well as in-flight data in Alaska. We observed that bad data occurred occasionally (at very warm temperatures) in MAS bands 10, 16, 19, and 20 in port 2. We plan to conduct MAS calibrations in the GSFC thermal vacuum chamber in November. These tests will assist in determining the final calibration coefficients for the visible and near-infrared channels for MAS.

Returning from ARMCAS, the CAR was set up in the Code 925 calibration lab and full calibrations were conducted using both the Goddard 6-foot integrating sphere and 48-inch integrating hemisphere. Preliminary analysis of these data showed that calibration was successful. A CAR OperatorÕs Manual was prepared to assist scientists flying or preparing to fly with the CAR onboard the University of Washington aircraft. This document, which was compiled, edited, and completed by Ward Meyer, describes the CAR instrument, operation, and scientific objectives, and presents selected results to illustrate details of the application of this sensor to varying operating conditions. We plan to create a CAR home page on World Wide Web to enable a much wider distribution of users of these datasets.

b. MODIS-related Data Processing and Algorithm Study

All CAR data are now stored on 8 mm Exabyte tapes. Jason Li has processed selected CAR data obtained during the Kuwait Oil Fire (Masy 1991), FIRE I marine stratocumulus (July 1986), and MAST (June 1992) experiments into HDF format. This standard format will be easier to use in analyzing diffusion domain data and surface bidirectional reflectance. A software GUI interface for viewing AVIRIS quicklook images was developed to be use in coordinating MAS data for ARMCAS and SCAR-B experiments.

Menghua Wang has delivered our MODIS Beta-3 cloud retrieval algorithm software for integration and testing. Specifically, this delivery includes: (i) a modification of the data input format for the cloud retrieval code made possible by creating an input file for easy input changes; (ii) a modification of the solar zenith angle inputs from theta0(J) to theta0(I, J) for the Ith pixel and Jth scan line to accommodate the MODIS input data format; (iii) an addition of cloud masking data input for each pixel - MASK(I, J) at the Ith pixel and Jth scan line [MASK(I, J)

= 0 and 1 are referred to cloudy and clear-sky pixels, respectively, for testing the flow of the cloud retrieval algorithm. The algorithm will be modified in upcoing months to use all cloud masking information (32 bit), e.g., to more properly assign cloudy or clear scene status]; and (iv) the addition of subroutine ATM_CORRECTION for making atmospheric corrections. The MASDAT subroutine has also been changed accordingly. In collaborating with the CERES science team, Steve Platnick finished working on atmospheric corrections for AVHRR and MAS data using the correlated k-distribution method for the 3.7 µm and thermal infrared channels, and MODTRAN for shorter wavelength channels. Several programmers from the NASA Langley Research Center CERES team are interacting with him to integrate this cloud retrieval code into their global AVHRR testing.

Simulations of CAR measurements using both discrete-ordinate (DisORT) and Monte Carlo radiative transfer codes were conducted by Robert Pincus to investigate: (i) what portion of a cloud appears to be in the diffusion domain (a function of azimuth angle), and (ii) to what extent the interpretation of CAR measurements is sensitive to, for example, the specification of single-scattering phase function. In collaborating with Alexander Marshak, Pincus has also examined how the internal radiation field in inhomogeneous clouds differs from the radiation field in homogeneous clouds. For example, by comparing the angular distribution of radiance as a function of optical depth, at some levels the homogenous cloud appeared to be in the diffusion domain (according to the CAR algorithm) but the Monte Carlo results always failed.

We have completed a sensitivity study using three MODIS spectral channels (1.38, 1.64, and 11 µm) to explore the effects exerted by uncertainties in cloud microphysics (e.g., particle size distribution) and cloud inhomogeneity on the apparent radiative properties, such as spectral reflectance and heating and cooling rate profiles of cirrus-like clouds. Results of this study suggest that: (i) while microphysical variations in the scattering and extinction functions of clouds affect the magnitudes of their spectral reflectances, cloud morphology significantly alters the shape of their angular distribution, (ii) spectral reflectances viewed near nadir are the least affected by cloud variability, and (iii) cloud morphology can lead to spectral heating and cooling rate profiles that differ substantially from their plane-parallel averaged equivalents. Since there are no horizontal thermal gradients in plane-parallel clouds, it may be difficult to correct for this deficiency. The title of this paper is ÒSpectral reflectance and atmospheric energetics in cirrus-like clouds. Part II: Applications of a Fourier-Riccati approach to radiative transferÓ and it will soon be submitted to the *Journal of the Atmospheric Sciences* for publication.

c. SCAR-B experiment

The SCAR-B (Smoke, Clouds, And Radiation - Brazil) was conducted successfully in Brazil from 16 August to 14 September 1995 as part of the MODIS

atmospheric science team activity. Michael King, Tom Arnold, Jason Li and Si-Chee Tsay participated in most of the SCAR-B operation and observation activities during this period. The MAS onboard the NASA ER-2 and the CAR onboard the University of WashingtonÕs C-131A aircraft performed well and acquired valuable data sets of the radiative properties of smoke, cloud, fire, and various surfaces. These data sets are currently being processed and will be available for all scientists involved to study the effects of biomass burning on atmospheric processes and remote sensing.

d. MODIS-related Services

1. Meetings

1. Steve Platnick attended the ONR/MAST science team meeting in London on 24-28 July 1995 and presented results analyzed from the ER-2 MAS dataset on ship tracks;

2. Menghua Wang attended the MODIS calibration support team workshop on 9 August 1995 at NASA Wallops Flight Facility and presented results from a study of atmospheric correction algorithms for ocean color sensors;

3. Si-Chee Tsay attended the Code 900 Monthly Technical Review on 11 August 1995 and presented a study of the effects of cloud inhomogeneity on atmospheric energetics and remote sensing using three MODIS channels;

4. Michael King attended the CERES science team meeting at NASA Langley Research Center on 20-22 September 1995 and presented an update on EOS as well as preliminary results acquired during the ARMCAS and SCAR-B campaigns;

5. Michael King gave presentations both to the press and to cabinet ministers in Brasilia at the mid-point of the SCAR-B experiment;

6. Michael King attended the National Research Council review of the US Global Change Research Program, with an emphasis on NASAÕs Mission to Planet Earth/EOS. He described NASAÕs plans for data validation with V. Ramanathan, Jerry Mahlman, and Ed Frieman, among others.

2. Seminars

1. Michael King gave a seminar entitled ÒBiomass Burning and Remote Sensing in Brazil,Ó while at Colorado College on 4 September to receive an honorary Doctor of Science degree.

2. Michael King gave a seminar at the National Center for Atmospheric Research on 6 September, entitled ÒClouds, Radiation and Climate from EOS.Ó

III. Anticipated Activities During the Next Quarter

a. Continue to analyze MAS data obtained from the MAST field campaign and compare with in situ microphysics measurements;

b. Continue to study the implementation of atmospheric corrections in our cloud retrieval algorithm;

c. Prepare and conduct MAS calibration in the GSFC thermal vacuum chamber in November;

d. Continue to analyze surface bidirectional reflectance measurements obtained by the CAR during the Kuwait Oil Fire, LEADEX, ASTEX, SCAR-A ARMCAS, and SCAR-B experiments, as well as analyze CAR diffusion domain data from MAST and FIRE I;

e. Prepare and analyze MAS, AVIRIS, and CLS data gathered during the ARMCAS campaign, as well as AVHRR, University of Washington C-131A in situ data, and surface data, all with the express purpose of helping to develop the MODIS cloud masking algorithm;

f. Prepare and analyze MAS, AVIRIS, and CLS data gathered during the US-Brazil SCAR-B campaign, as well as University of Washington C-131A in situ and radiation data to study aerosol-cloud interactions;

g. Attend NASA/AIP/TARFOX and MODIS Science Team meetings in Columbia (October 30 - November 3, 1995) and GSFC (November 15-17, 1995), respectively.

h. Attend the EOS Payload Panel meeting in Annapolis on November 28-30, 1995.

IV. Problems/Corrective Actions

No problems that we are aware of at this time.

V. Publications

1. King, M. D., D. D. Herring and D. J. Diner, 1995: The Earth Observing System (EOS): A space-based program for assessing mankindÕs impact on the global environment. *Opt. Photon. News*, **6**, 34_39.

2. Gumley, L. E., and M. D. King, 1995: Remote sensing of flooding in the US upper midwest during the summer of 1993. *Bull. Amer. Meteor. Soc.*, **76**, 933_943.

3. King, M. D., S. C. Tsay and S. Platnick, 1995: In situ observations of the indirect effects of aerosol on clouds. *Aerosol Forcing of Climate*, R. J. Charlson and J. Heintzenberg, Eds., John Wiley and Sons, 227_248.

4. Schwartz, S. E., F. Arnold, J. P. Blanchet, P. A. Durkee, D. J. Hofmann, W. A. Hoppel, M. D. King, A. A. Lacis, T. Nakajima, J. A. Ogren and O. B. Toon, 1995: Group report: Connections between aerosol properties and forcing of climate. *Aerosol Forcing of Climate*, R. J. Charlson and J. Heintzenberg, Eds., John Wiley and Sons, 251_280.

5. Platnick, S., and F. J. P. Valero, 1995: A validation of a satellite cloud retrieval during ASTEX. *J. Atmos. Sci.*, **52**, 2985_3001.

6. King, M. D., and M. K. Hobish, 1995: Satellite instrumentation and imagery. *Encyclopedia of Climate and Weather*, Oxford University Press (in press).

7. Wielicki, B. A., R. D. Cess, M. D. King, D. A. Randall and E. F. Harrison, 1995: Mission to Planet Earth: Role of clouds and radiation in climate. *Bull. Amer. Meteor. Soc.* (in press).

8. Tsay, S. C., M. D. King and P. V. Hobbs, 1995: Arctic radiation measurements in column atmosphere-surface system - Science Plan. NASA GSFC internal report.

9. King, M. D., W. P. Menzel, P. S. Grant, J. S. Myers, G. T. Arnold, S. E. Platnick, L. E. Gumley, S. C. Tsay, C. C. Moeller, M. Fitzgerald, K. S. Brown and F. G. Osterwisch, 1995: Airborne scanning spectrometer for remote sensing of cloud, aerosol, water vapor and surface properties. Submitted to *J. Atmos. Oceanic Technol.*

10. Tsay, S. C., P. M. Gabriel, M. D. King and G. L. Stephens, 1995: Spectral reflectance and atmospheric energetics in cirrus-like clouds. Part II: Applications of a Fourier-Riccati approach to radiative transfer. Submitted to *J. Atmos. Sci.*